MODULE- 1

IRRIGATION ENGINEERING

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Content…

Necessity of irrigation- scope of irrigation engineering- benefits and ill effects of irrigation- irrigation development in India- types of irrigation systems, Soil-water plant relationship: Classification of soil water- soil moisture contents- depth of soil water available to plants- permanent and ultimate wilting point

Course goals

This course has two specific goals:

(i) To introduce students to basic concepts of soil, water, plants, their interactions, as well as irrigation and drainage systems design, planning and management.

(ii) To develop analytical skills relevant to the areas mentioned in (i) above, particularly the design of irrigation and drainage projects.

Introduction…

- Irrigation is the artificial application of water to the land or soil.
- It is used to assist in the growing of agricultural crops, maintenance of landscapes, and revegetation of disturbed soils in dry areas and during periods of inadequate rainfall.
- Irrigation is often studied together with drainage, which is the natural or artificial removal of surface and sub-surface water from a given area.

Irrigation engineering: involves

- Conception,
- Planning,
- Design,
- Construction,
- Operation and
- Management of an irrigation system.

Necessity of irrigation...

- Insufficient rainfall
- Uneven distribution of rainfall
- Improvement of perennial crop
- Development of agriculture in desert area

Benefits of irrigation...

- Increase in crop yield
- Protection from famine
- Cultivation of superior crops
- Elimination of mixed cropping
- Economic development
- Hydro power generation
- Domestic and industrial water supply

ill effects of irrigation...

- Rising of water table
- Formation of marshy land
- Dampness in weather
- Loss of valuable lands

Irrigation development in India...

- Among Asian countries India has largest arable land (40%).
- Only USA has more arable land than India.
- In a monsoon climate and an agrarian economy like India, irrigation has played a major role in the production process. There is evidence of the practice of irrigation since the establishment of settled agriculture during the Indus Valley Civilization (2500 BC).

- These irrigation technologies were in the form of small and minor works, which could be operated by small households to irrigate small patches of land and did not require co-operative effort.
- In the south, perennial irrigation may have begun with construction of the Grand Anicut by the Cholas as early as second century to provide irrigation from the Cauvery river.

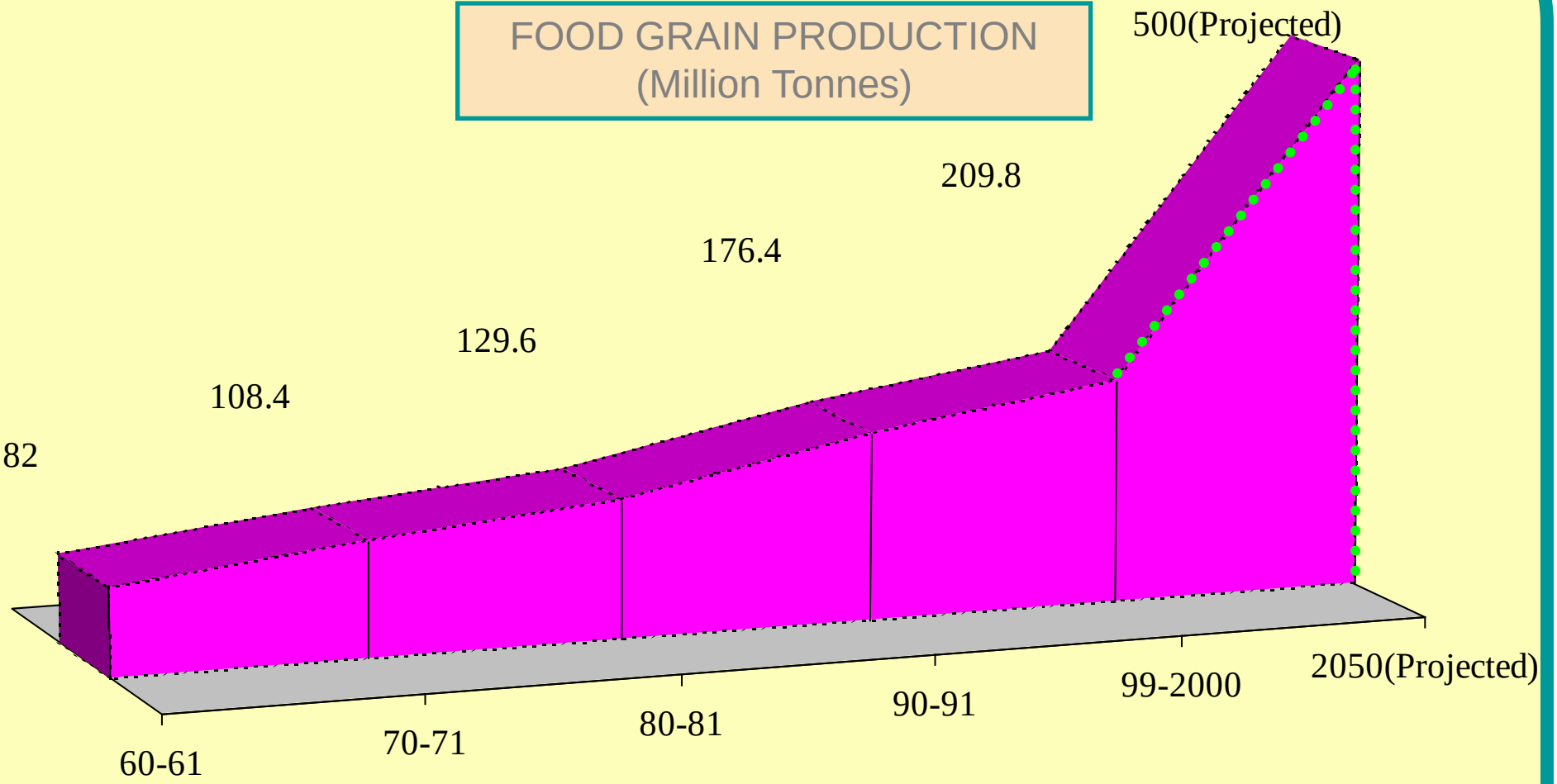
- At beginning of 19th century, there was large no of water tanks in peninsular India and several canals in northern India were build.

- The upper Ganga canal, upper Bari Doab canal and the Krishna and Godavari delta system were constructed between 1836-1866.

- During the last fifty years, gross irrigated area (GIA) of India has increased more than three fold from 22 to 76 million Hectares.

INDIA

FOOD GRAIN PRODUCTION
(Million Tonnes)



YEAR

- Groundwater irrigation in India developed during the period of green revolution and contributed much in increasing the gross irrigated area of the country.
- In the last five decades, groundwater irrigation has increased from 5 million hectares to 35million hectares.

Classification of irrigation schemes ...

Irrigation projects in India are classified into three categories

- major
- medium &
- minor

according to the area cultivated.

1) Major irrigation projects: projects which have a culturable command area (CCA) of more than 10,000 ha but more than 2,000 ha utilize mostly surface water resources.

2) Medium irrigation projects: projects which have CCA less than 10,000 ha. But more than 2,000 ha utilizes mostly surface water resources.

3) Minor irrigation projects: projects with CCA less than or equal to 2,000 ha. utilizes both ground water and local surface water resources.

Outlook of the national water policy

- Our country had adapted a national water policy in the year 1987 which was revised in 2002.

- The policy document lays down the fact that planning and development of water resources should be governed by the national perspective.

Aspects related to irrigation from the policy

- Irrigation planning either in an individual project or in a watershed as a whole should take into account the irrigability of land, cost-effective irrigation options possible from all available sources of water and appropriate irrigation techniques for optimizing water use efficiency.

- There should be a close integration of water use and land use policies.

- Water allocation in an irrigation system should be done with due regard to equity and social justice.

- Concerted efforts should be made to ensure that the irrigation potential created is fully utilised.

- Irrigation being the largest consumer of fresh water, the aim should be to get optimal productivity per unit of water.

Types of irrigation systems...

The classification of the irrigation systems can also be based on the way the water is applied to the agricultural land as –

1. Flow irrigation system: where the irrigation water is conveyed by growing to the irrigated land.

   - Direct irrigation
   - Reservoir/tank/storage irrigation

2. Lift irrigation system: Where the irrigation water is available at a level lower than that of the land to be irrigated and hence the water is lifted up by pumps or by other mechanical devices for lifting water and conveyed to the agricultural land through channels flowing under gravity.

Classification of irrigation systems may also be made on the basis of duration of the applied water.

1. Inundation/flooding type irrigation system: In which large quantities of water flowing in a river during floods is allowed to inundate the land to be cultivated, thereby saturating the soil.

   - The excess water is then drained off and the land is used for cultivation.

   - It is also common in the areas near river deltas, where the slope of the river and land is small.

2. Perennial irrigation system: In which irrigation water is supplied according to the crop water requirement at regular intervals, throughout the life cycle of the crop.

- The water for such irrigation may be obtained from rivers or from wells.

Some important terms

1. Culturable Command Area (CCA): The gross command area contains unfertile barren land, alkaline soil, local ponds, villages and other areas as habitation.

   These areas are called unculturable areas. The remaining area on which crops can be grown satisfactorily is known as cultivable command area (CCA).

Culturable command area can further be divided into 2 categories

- Culturable cultivated area: It is the area in which crop is grown at a particular time or crop season.

- Culturable uncultivated area: It is the area in which crop is not sown in a particular season.

2. Gross command area (GCA): The total area lying between drainage boundaries which can be commanded or irrigated by a canal system.

   G.C.A = C.C.A + unculturable area

3. Water Tanks: These are dug areas of lands for storing excess rain water.

4. Water logged area: An agricultural land is said to be waterlogged when its productivity or fertility is affected by high water table.

The depth of water-table at which it tends to make the soil water-logged and harmful to the growth and subsistence of plant life depends upon the height of capillary fringe.

The height of capillary fringe is more for fine grained soil and less for coarse grained ones.

5. Outlet: This is a small structure which admits water from the distributing channel to a water course of field channel. Thus an outlet is a sort of head regulator for the field channel delivering water to the irrigation fields.

6. Permanent wilting point: or the wilting coefficient is that water content at which plants can no longer extract sufficient water from the soil for its growth.

Soil Water Relationships

Objective 1

Explain the relationships between soil properties and water retention.

Vocabulary Terms

- Potable- drinkable, free from contaminants.
- Irrigation- addition of water to plants to supplement water provided by rain or snow.
- Water Cycle – the cycling of water among the water sources to surface, to atmosphere, back to surface.

Vocabulary Terms

- Precipitation – falling products of condensation in the atmosphere, as rain, snow, or hail.

- Evaporation – to change from a liquid or solid state to a vapor or gas.

- Saturate – this happens to soil when water is added until all the spaces or pores are filled.

Types of Groundwater

- Gravitational – also called "free water."

- This is the water that drains out of the soil after it has been wetted.

- This water moves downward through the soil because of the pull of gravity.

- This water also feeds wells and springs.

Types of Groundwater

- Capillary – water that moves into and is held in the soil by capillary forces (or pertaining to the attraction or repulsion between a solid and a liquid).

  - Plant roots can absorb or take up this moisture.

  - The size of the soil pore will influence the amount of water held by capillary forces.

  - Provides most of the moisture for plant growth.

Types of Groundwater

- Hygroscopic - very thin water films around the soil particles.

 - These films are held by extremely strong forces that cause the water molecules to be arranged in a semi-solid form.

 - This water is unavailable to plants.

How is Soil Water Classified?

1) Hygroscopic Water is held so strongly by the soil particles (adhesion), that it is not available to the plants.
2) Capillary Water is held by cohesive forces greater than gravity and is available to plants.
3) Gravitational Water is that water which cannot be held against gravity.
   - as water is pulled down through the soil, nutrients are "leached" out of the soil (nitrogen)

Levels of Water in Soil

- Saturation Point – the moisture point at which all of the pore spaces are filled with water.

- Occurs when an area receives a lot of rain on a daily basis and the water does not get absorbed by plants, evaporation is at a low do to the lack of sunlight, and runoff areas (ditches, drains) are to capacity.

Levels of Water in Soil

- Field Capacity – the maximum amount of water left in the soil after losses of water to the forces of gravity have ceased and before surface evaporation begins.

 - Occurs when the soil contains the maximum amount of capillary water.

Levels of Water in Soil

- Wilting Point – the point at which the plant can no longer obtain sufficient water from the soil to meet its transpiration needs.

 - At this point the plant enters permanent wilt and dies.

Levels of Water in Soil

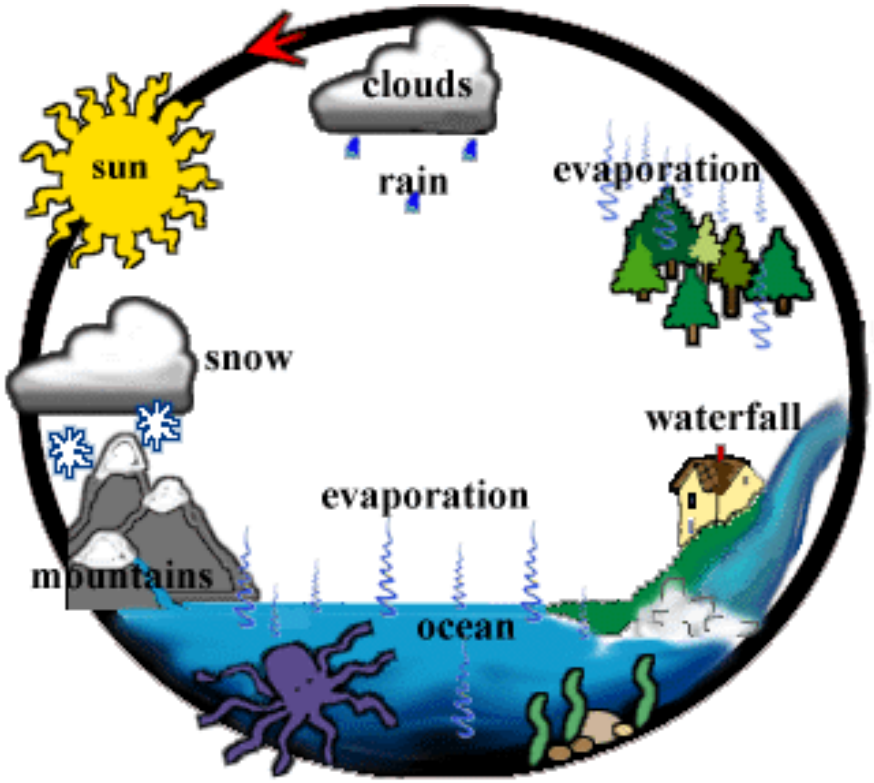
- Available Soil Water – that amount present in a soil which can be moved by plants.

 - It is designated as the difference between the field capacity and the wilting point.

The Hydrolic (Water) Cycle

- Water is constantly moving through the atmosphere and into and out of the soil.

- Soil moisture is one portion of the cycle which can be controlled to the greatest extent by affecting the soil.



How Does Water Enter the Soil?

- through pores in the soil
- sandy soils have the largest pores, but are often filled with other material
- medium textured soils (loamy) have good water entry properties
- clays, pores swell shut when they get wet

Objective 2

Explain the relationships between soil water and plant growth.

Vocabulary Terms

- Water Holding Capacity – is a soil property which represents the amount of water a soil can retain after it has been saturated by rain and downward movement has ceased.

- Transpiration – the process by which water, as a vapor, is lost by living plants.

Vocabulary Terms

- Translocation – the process by which water moves through a plant from the roots to the leaves.
- Wilting Point – the moisture content of a soil in which growing plants wilt and will not recover after water is added.

Vocabulary Terms

- Evapotranspiration - the combination of water that is lost from the soil through *evaporation* and through *transpiration* from plants as a part of their metabolic processes
- Adhesion – the attraction of two different molecules (water to soil)
- Cohesion – the attraction of two similar molecules (water to water)

Water Holding Capacities of Soils

- The amount of water a soil can retain is influenced by:
  - soil texture
  - soil structure
  - organic matter.

Soil Texture

- The smaller the soil particles, the greater the soil's water holding capacity. Clay has more water holding capacity than sand.

- Small soil particles (clay) have more small pores or capillary spaces, so they have a higher water holding capacity. Large soil particles (sand) have fewer capillary spaces, therefore less ability to hold water.

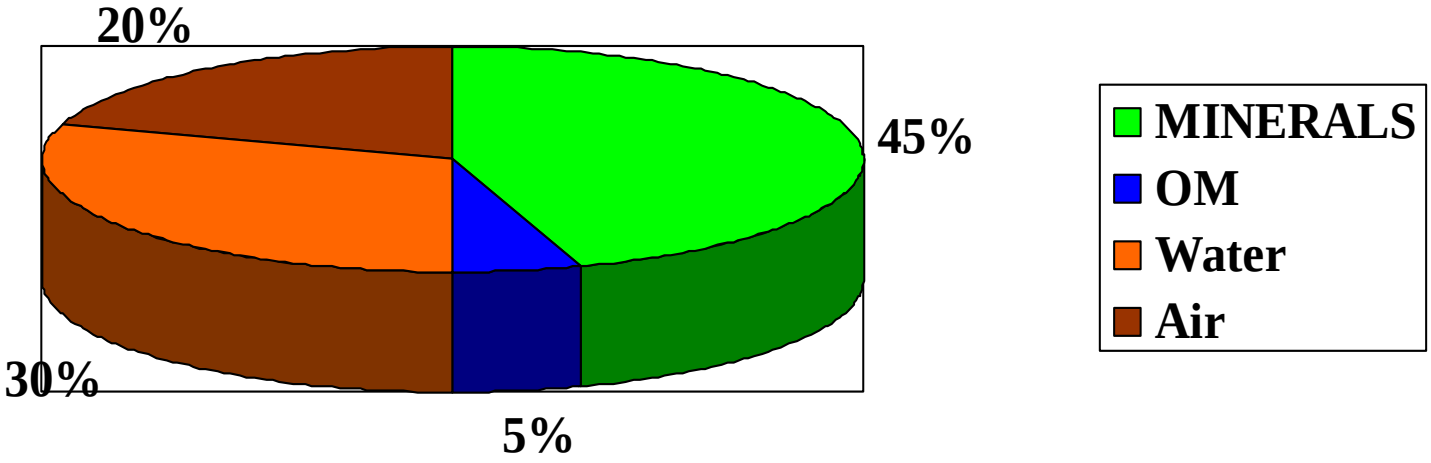
Soil Structure

- A soil structure has a direct correlation to the amount of water it can retain.

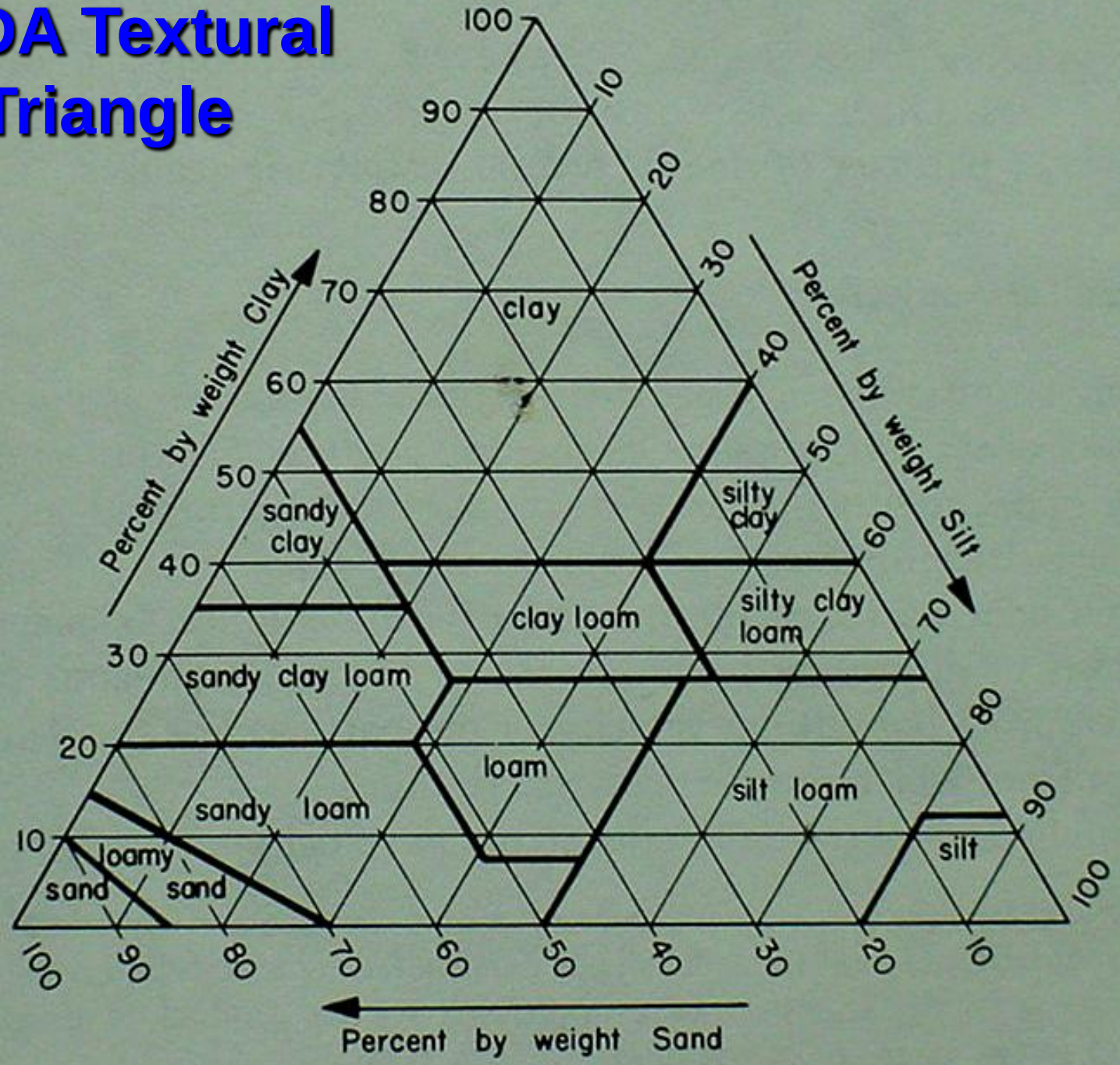
Organic Matter

- Organic matter aids in cementing particles of clay, silt, and sand together into aggregates which increases the water holding capacity.
- Decomposition of organic matter also adds vital nutrients to the soil.

Proportions of soil constituents



USDA Textural Triangle



- Bulk Density (ρ_b) $$\rho_b = \frac{M_s}{V_b}$$

  - ρ_b = soil bulk density, g/cm^3
  - M_s = mass of dry soil, g
  - V_b = volume of soil sample, cm^3

  Typical values: 1.1 - 1.6 g/cm^3

- Particle Density (ρ_p) $$\rho_p = \frac{M_s}{V_s}$$

  - ρ_P = soil particle density, g/cm^3
  - M_s = mass of dry soil, g
  - V_s = volume of solids, cm^3

  Typical values: 2.6 - 2.7 g/cm^3

- Porosity (ϕ)

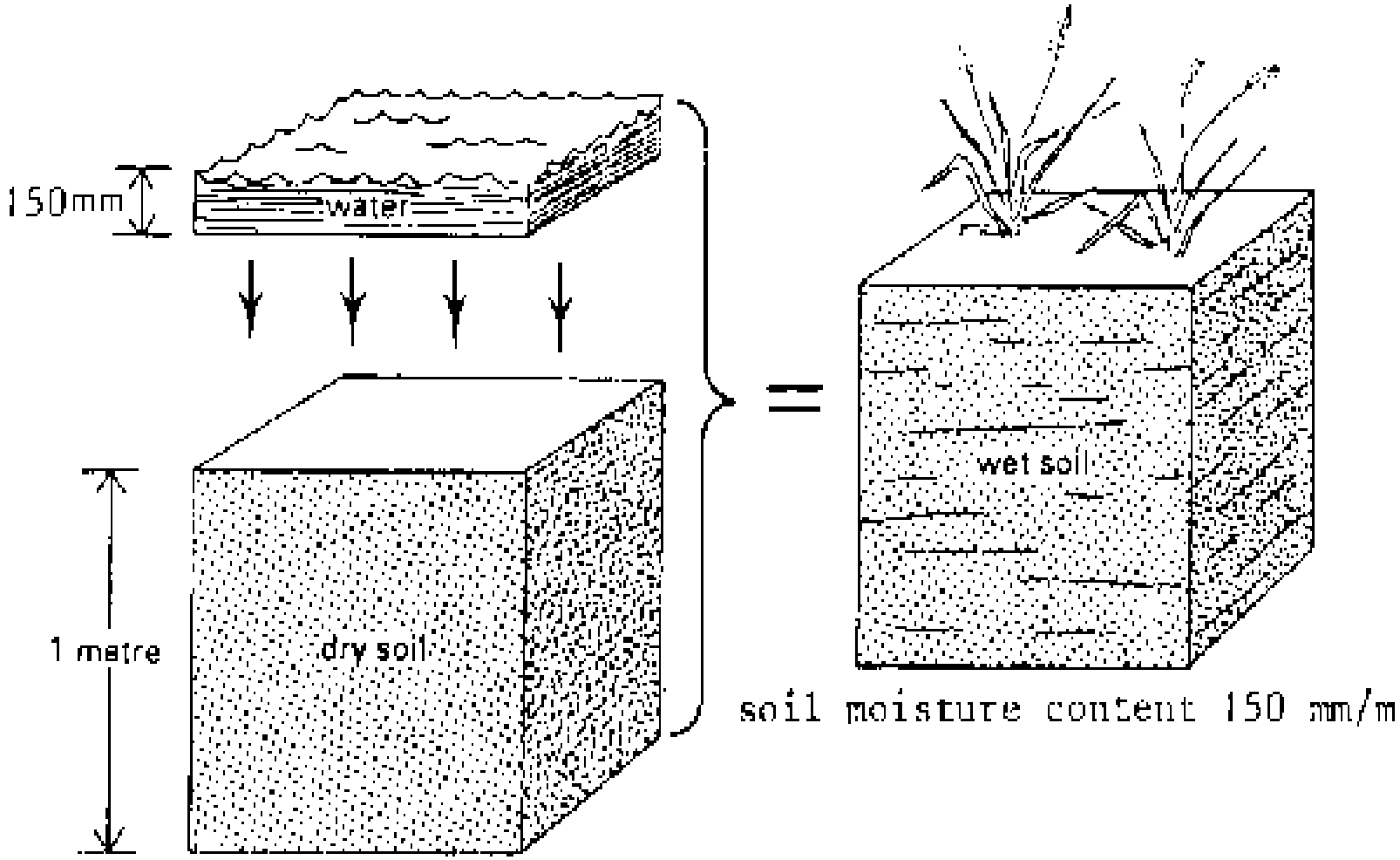
$$\phi = \frac{\text{volume of pores}}{\text{volume of soil}}$$

$$\phi = \left(1 - \frac{\rho_b}{\rho_p}\right)100\%$$

- Typical values: 30 - 60%

Soil moisture content

- The soil moisture content indicates the amount of water present in the soil.
- It is commonly expressed as the amount of water (in mm of water depth) present in a depth of one metre of soil.
- For example: when an amount of water (in mm of water depth) of 150 mm is present in a depth of one metre of soil, the soil moisture content is 150 mm/m


150mm
water
1 metre
dry soil
wet soil
soil moisture content 150 mm/m

Water in Soils

- Soil water content

$$\theta_m = \frac{M_w}{M_s}$$

  - Mass water content (θ_m)
  - θ_m = mass water content (fraction)
  - M_w = mass of water evaporated, g (≥24 hours @ 105°C)
  - M_s = mass of dry soil, g

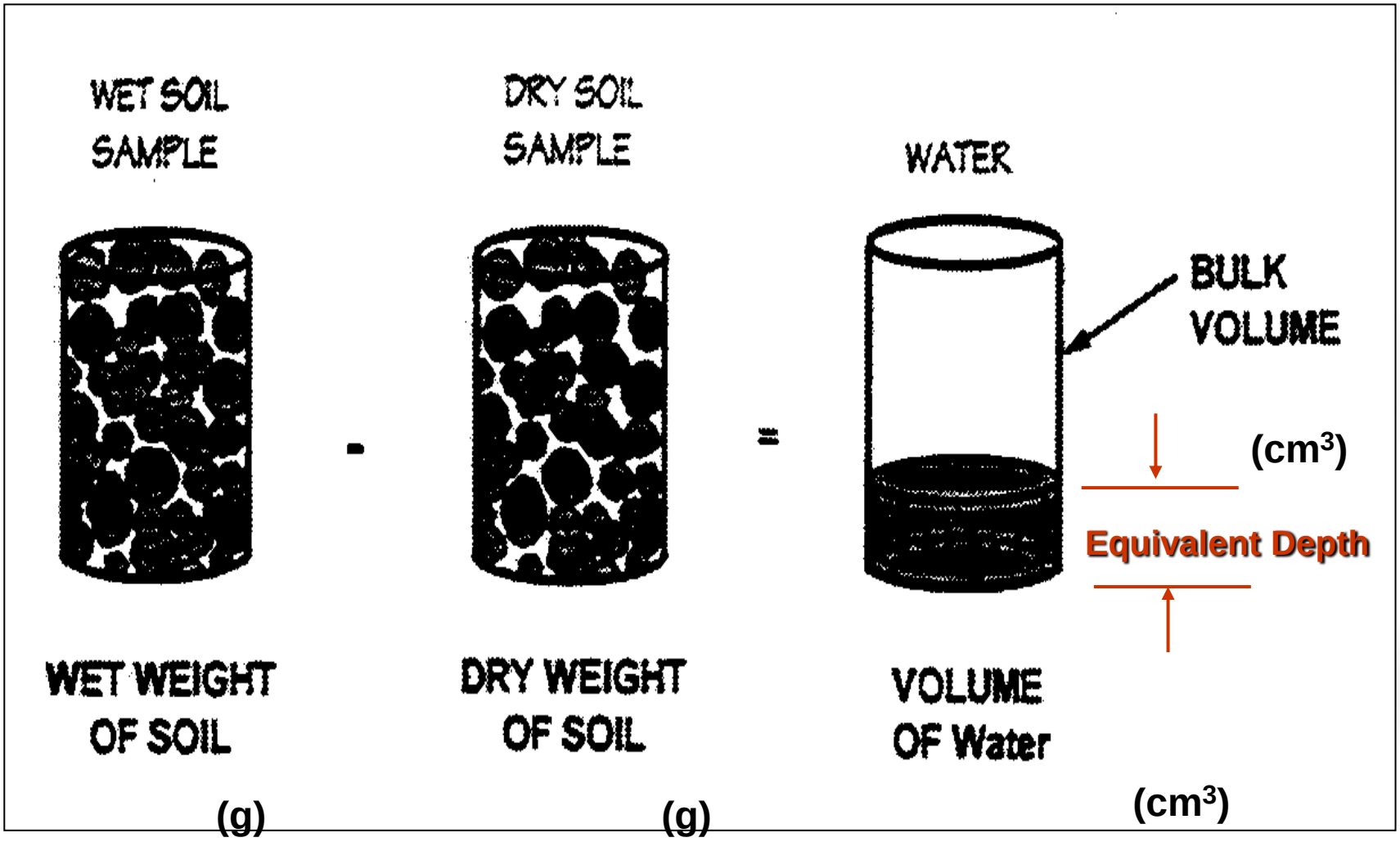
- Volumetric water content (θ_v)

$$\theta_v = \frac{V_w}{V_b}$$

- θ_V = volumetric water content (fraction)
- V_w = volume of water
- V_b = volume of soil sample
- At saturation, $\theta_V = \phi$
- θ_V = As θ_m
- As = apparent soil specific gravity = ρ_b/ρ_w
  (ρ_w = density of water = 1 g/cm^3)
- As = ρ_b numerically when units of g/cm^3 are used

- Equivalent depth of water (d)
  - d = volume of water per unit land area = $(\theta_v \mathbf{A}\ \mathbf{L}) / \mathbf{A} = \theta_v \mathbf{L}$
  - d = equivalent depth of water in a soil layer
  - **L** = depth (thickness) of the soil layer

Volumetric Water Content & Equivalent Depth



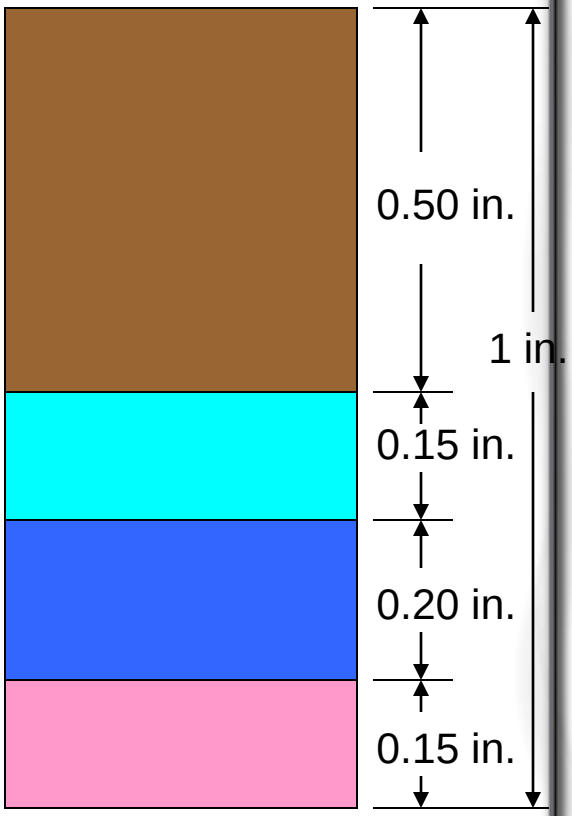
Volumetric Water Content & Equivalent Depth

Typical Values for Agricultural Soils

Soil Solids (Particles): 50%

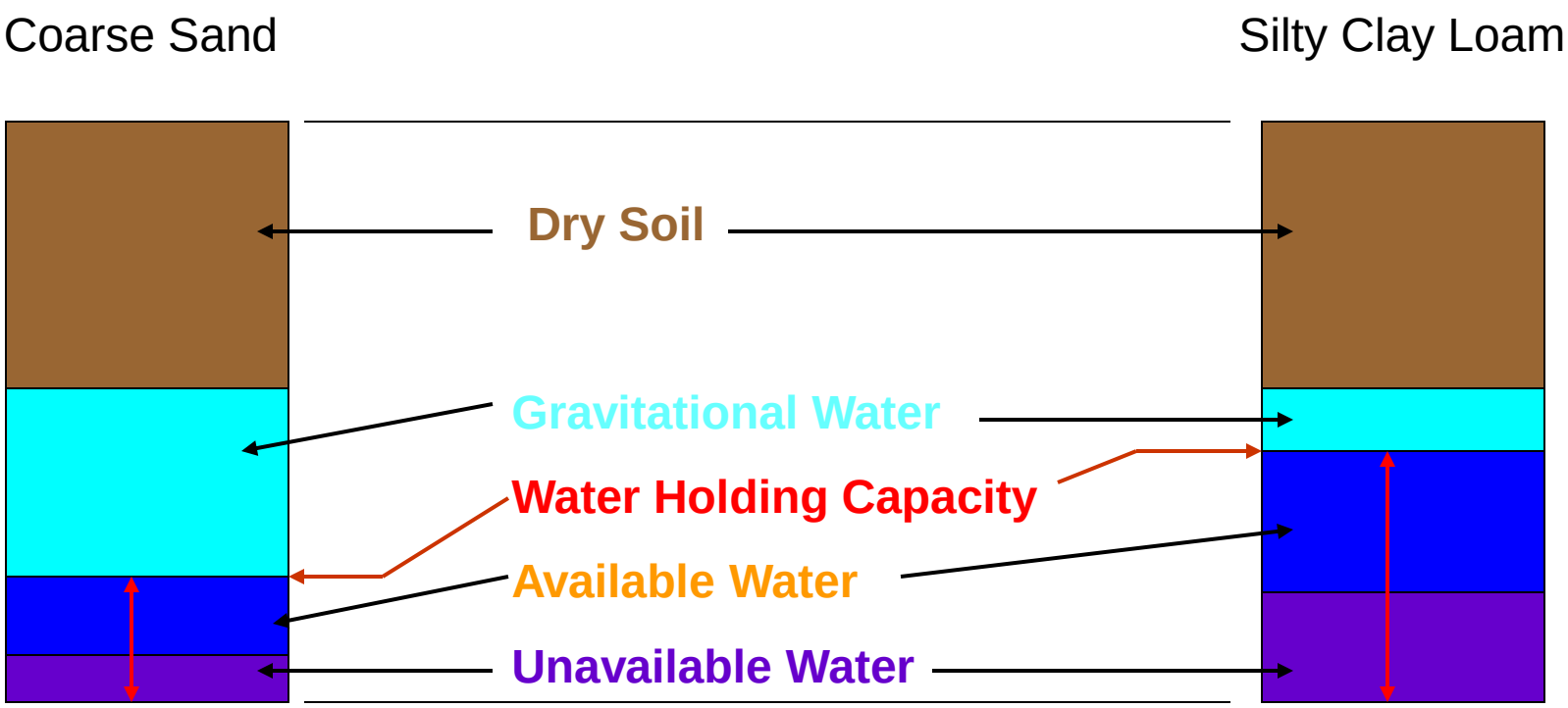
Total Pore Space: 50%

- Very Large Pores: 15% (Gravitational Water)
- Medium-sized Pores: 20% (Plant Available Water)
- Very Small Pores: 15% (Unavailable Water)



Water-Holding Capacity of Soil

Effect of Soil Texture



Soil water constants

- For a particular soil, certain soil water proportions are defined which dictate whether the water is available or not for plant growth.

- These are called the soil water constants, which are described below.

- Saturation capacity: this is the total water content of the soil when all the pores of the soil are filled with water.
- It is also termed as the maximum water holding capacity of the soil.
- At saturation capacity, the soil moisture tension is almost equal to zero.

- Field capacity: this is the water retained by an initially saturated soil against the force of gravity.
- Hence, as the gravitational water gets drained off from the soil, it is said to reach the field capacity.
- At field capacity, the macro-pores of the soil are drained off, but water is retained in the micropores.

- Permanent wilting point: plant roots are able to extract water from a soil matrix, which is saturated up to field capacity.
- However, as the water extraction proceeds, the moisture content diminishes and the negative pressure increases.
- At one point, the plant cannot extract any further water and thus wilts.

Two stages of wilting points are recognized and they are:

- Temporary wilting point: this denotes the soil water content at which the plant wilts at day time, but recovers during right or when water is added to the soil.

- Ultimate wilting point: at such a soil water content, the plant wilts and fails to regain life even after addition of water to soil.

It must be noted that the above water contents are expressed as percentage of water held in the soil pores, compared to a fully saturated soil.

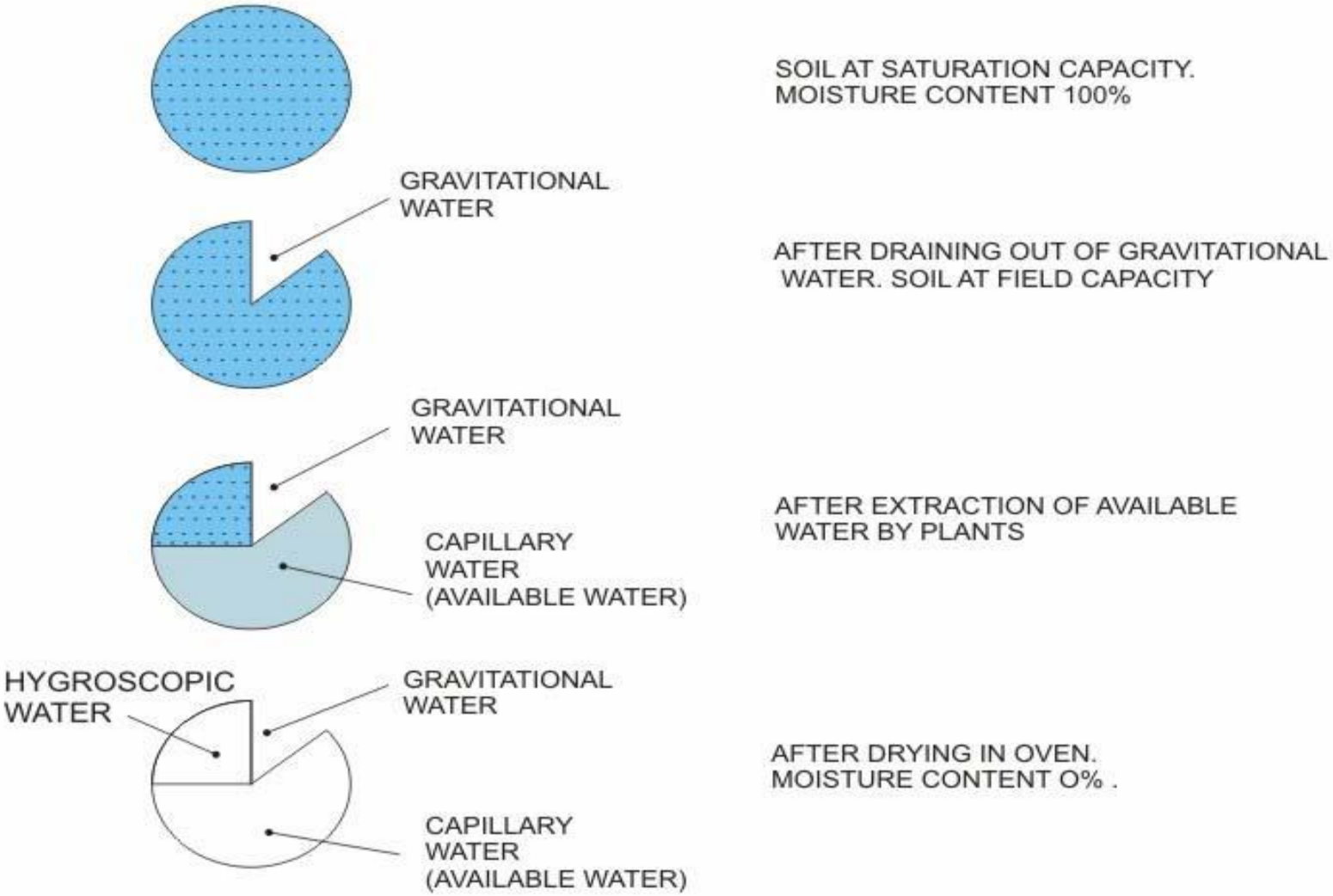


FIGURE 2 . **Classification of soil water**

Available Water

- Water held in the soil between field capacity and permanent wilting point
- "Available" for plant use

- Available Water Capacity (AWC)

- AWC = $\theta_{fc} - \theta_{wp}$
- Units: depth of available water per unit depth of soil, "unitless" (in/in, or mm/mm)
- Measured using field or laboratory methods

Soil Hydraulic Properties and Soil Texture

Table 2.3. Example values of soil water characteristics for various soil textures.*

Soil texture	θ_{fc}	θ_{wp}	AWC
	---------- in/in or m/m	---------	
Coarse sand	0.10	0.05	0.05
Sand	0.15	0.07	0.08
Loamy sand	0.18	0.07	0.11
Sandy loam	0.20	0.08	0.12
Loam	0.25	0.10	0.15
Silt loam	0.30	0.12	0.18
Silty clay loam	0.38	0.22	0.16
Clay loam	0.40	0.25	0.15
Silty clay	0.40	0.27	0.13
Clay	0.40	0.28	0.12

* Example values are given. You can expect considerable variation from these values within each soil texture.

- Fraction available water depleted (f_d)

$$f_d = \left(\frac{\theta_{fc} - \theta_v}{\theta_{fc} - \theta_{wp}} \right)$$

  - (θ_{fc} - θ_v) = soil water deficit (SWD)
  - θ_v = current soil volumetric water content

- Fraction available water remaining (f_r)

$$f_r = \left(\frac{\theta_v - \theta_{wp}}{\theta_{fc} - \theta_{wp}} \right)$$

  - (θ_v - θ_{wp}) = soil water balance (SWB)

➢ Total Available Water (TAW)

$TAW = (AWC)\ (R_d)$

- TAW = total available water capacity within the plant root zone, (inches)
- AWC = available water capacity of the soil, (inches of H_2O/inch of soil)
- R_d = depth of the plant root zone, (inches)
- If different soil layers have different AWC's, need to sum up the layer-by-layer TAW's

$TAW = (AWC_1)\ (L_1) + (AWC_2)\ (L_2) + \ldots (AWC_N)\ (L_N)$

- L = thickness of soil layer, (inches)
- $_{1, 2, N}$: subscripts represent each successive soil layer

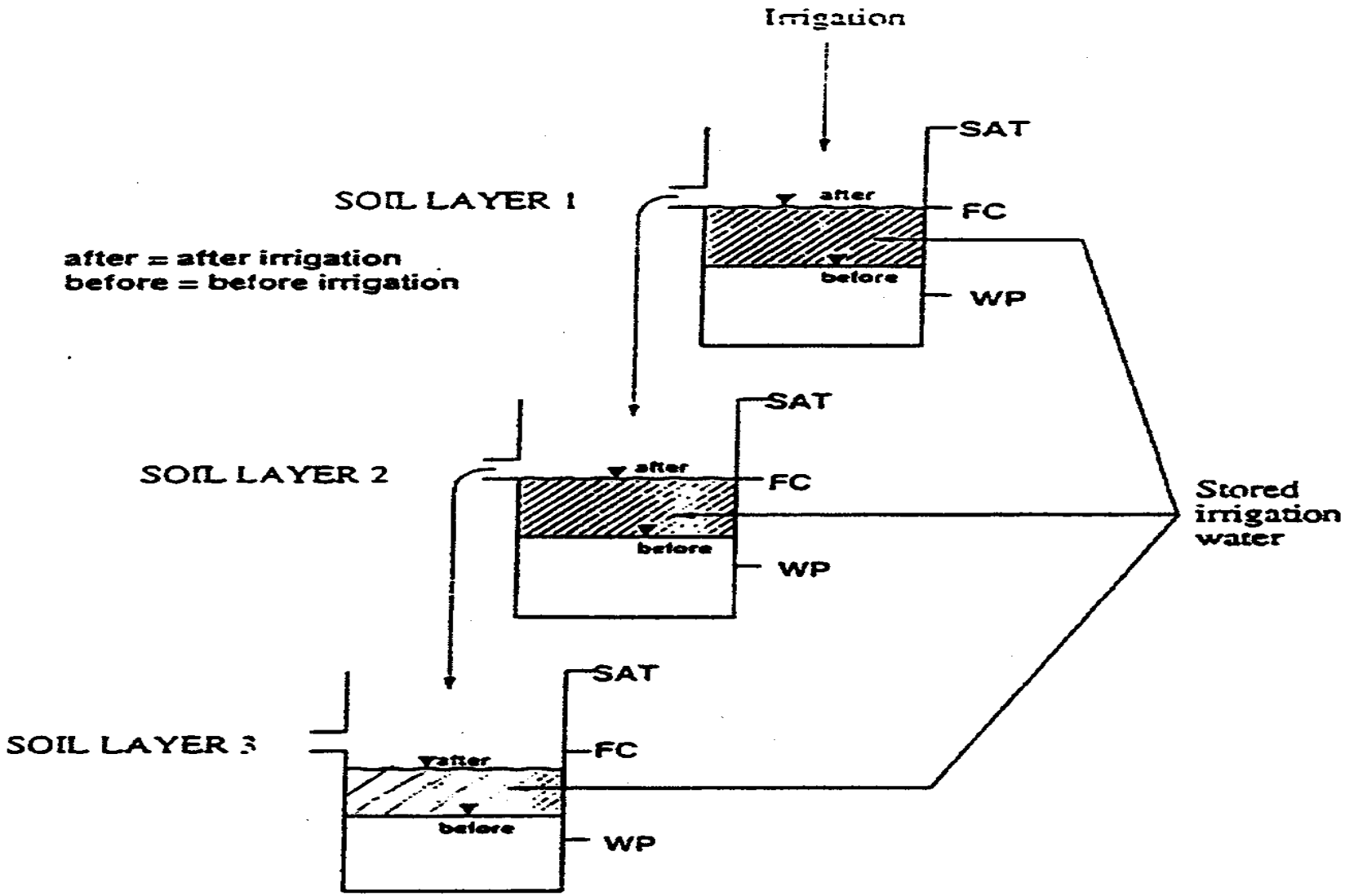
Depth of Penetration

- Can be viewed as sequentially filling the soil profile in layers

- Deep percolation: water penetrating deeper than the bottom of the root zone

- Leaching: transport of chemicals from the root zone due to deep percolation

Water Storage in Layered Soil Profiles



Water requirements of crops

Content…

Depth of water applied during irrigation- Duty of water and delta improvement of duty- command area and intensity of irrigation consumptive use of water and Evapotranspiration- irrigation efficiencies- assessment of irrigation water.

Introduction…

- The term water requirements of a crop means the total quantity of all water and the way in which a crop requires water, from the time it is sown to the time it is harvested.
- The water requirement of crop varies with the crop as well as with the place.
- The same crop may have different water requirements at different places of the same country.

Factors affecting water requirement

- Water table: high water table less requirement, vice versa.
- Climate: In hot climate evaporation loss is more, hence requirement more, vice versa.
- Ground slope: ground is steep, the water flows down very quickly and soil gets little time to absorb, so requirement more. If ground is flat less requirement.

- Intensity of irrigation: if intensity of irrigation for a particular crop is high, then more area comes under the irrigation system and requirement is more, vice versa.
- Type of soil: sandy soil water percolates very quickly, so requirement is more. Clay soil retention capacity is more, so less requirement.
- Method of application of water: surface method more water is required to meet up evaporation. In sub surface and sprinkler method less water required.

- Method of ploughing: In deep ploughing less water required, because soil can retain moisture for longer period. In shallow ploughing more water required.

Base

- Base is defined as the period from the first to the last watering of the crop just before its maturity.
- Also known as base period.
- Denoted as “B” and expressed in no of days.

Crop	Base in days
Rice	120
Wheat	120
Maize	100
Cotton	200
Sugarcane	320

Delta

- Each crop requires certain amount of water per hectare for its maturity.
- If the total of amount of water supplied to the crop is stored on the land without any loss, then there will be a thick of water standing on the land.
- This depth of water layer is known as Delta for the crop.
- Donated by "Δ" expressed on cm.

Kharif crop	Delta in cm
Rice	125
Maize	45
Ground nut	30
Millet	30
Rabi crop	Delta in cm
Wheat	40
Mustard	45
Gram	30
Potato	75

Duty

- Duty of water is defined as no of hectares that can be irrigated by constant supply of water at the rate of one cumec throughout the base period.
- Denoted as "D" and expressed in hectares/cumec.
- Varies with soil condition, method of ploughing, method of application of water.
- 1 cumec-day = 1 m^3/sec for one day.

Crop	Duty in hectares/cumec
Rice	900
Wheat	1800
Cotton	1400
Sugarcane	800

Factors affecting duty

- Soil characteristics: if soil of the canal bed is porous and coarse grained, it leads to more seepage loss and low duty. If soil is compact and close grained, seepage loss will less and high duty.
- Climatic condition: when atmospheric temp. of command area becomes high, the evaporation loss is more and duty becomes low and vice versa.

- Rainfall: if rainfall is sufficient during crop period, less quantity of irrigation water shall be required and duty will more and vice versa.
- Base period: when base period is longer, the water requirement will be more and duty will low and vice versa.
- Type of crop: water requirement of various crops are different. So the duty also varies.
- Topography of agricultural land: if land has slight slope duty will high as water requirement optimum. As slope increases duty increases because there is wastage of water.

- Method of ploughing: deep ploughing by tractor requires less quantity of water, duty is high. Shallow ploughing by bullocks requires more quantity of water, duty is low.
- Methods of irrigation: duty is high in case of perennial irrigation system as compared to inundation irrigation system. Because in perennial system head regulator is used.
- Water tax: if some tax is imposed on the basis of volume of water consumption, the farmer will use the water economically, duty will be high.

Methods of improving duty

- Proper ploughing: Ploughing should be done properly and deeply, so that moisture retaining capacity of soil is increased.
- Methods of supplying water: this should be decided according to the field and soil conditions.

Furrow method – crops shown in row

Contour method – hilly area

Basin method – for orchards

Flooding method – plain lands

- Canal lining: to reduce percolation loss the canals should be lined according to site condition.
- Transmission loss: to reduce this canals should be taken close to the irrigable land as far as possible.
- Crop rotation: crop rotation should be adopted to increase the moisture retaining capacity and fertility of the soil.
- Implementation of tax: the water tax should be imposed on the basis of volume of water consumption.

Relation between Base, Delta and Duty

Let,

D = duty of water in hectare/cumec

B = base in days

Δ = delta in m

From definition, one cumec of water flowing continuously for "B" days gives a depth of water Δ over an area "D" hectares. i.e.

1 cumec for 1 days gives Δ over D/B hectares.

or

1 cumec for B days gives Δ over D/B hectares.

or

1 cumec for 1 day = (D/B) $\times$ Δ hectare – meter

1 cumec- day = (D/B) $\times$ Δ hectare – meter ----- (i)

Again, 1 cumec- day = $1 \times 24 \times 60 \times 60 = 86400\ m^3$ =

8.64 hectare – meter ------- (ii)

(1 hectare = 10, 000 m^2)

From (i) & (ii) = (D/B) $\times$ Δ = 8.64

$$\Delta = (8.64 \times B)/\ D = \text{in m.}$$

Command area

- "The area which lies on down stream side of project to which water can reach by gravity action."
- There are the three types of commanded areas.

Gross Commanded Area (G.C.A)

- The Gross commanded area is the total area lying between drainage boundaries which can be irrigated by a canal system.

Cultivable Commanded Area (C.C.A)

- It is the net area, which can be irrigated by a canal system. It includes all land on which cultivation is possible, though all area may not be under cultivation at the time.
- G.C.A. = C.C.A. + Uncultivable area

Irrigable Commanded Area (1.C.A)

- It is the part of cultivable commanded area, which can be irrigated. All the
- C.C.A. cannot be irrigated because of high elevation.

Intensity of Irrigation

- It is the ratio of area irrigated per season to total irrigable areas or small projects is based on this.

Types of soil

- Alluvial soil: formed by deposition of silt carried by river water during flood.
- Silt is formed due to weathering action of rocks by heavy current of river water in the hilly regions.
- Found in Indo –Gangetic plains, Brahmaputra plains.

- Black soil: originated by weathering action on rocks like granite, basalt etc.
- Mainly found in AP, MP, TN, Gujarat.
- They are sticky when wet and very hard when dry.
- Suitable for cultivation of cotton.

- Red soil: formed by weathering action of rocks of igneous and metamorphic group.
- Water absorbing capacity very low.
- Found in Karnataka, TN, Orissa, WB, Maharashtra etc.

- Laterite soil: formed by weathering action of laterite rocks.
- Yellowish red in color and having good drainage property.
- Found in Kerala, Karnataka, Orissa, Assam etc.

Consumptive use of water

- It is defined as total quantity of water used for the growth of plants by transpiration and the amount of lost by evaporation.
- It is also known as evapo-transpiration.
- Expressed in hectare-meter or as depth of water in m.
- The value of consumptive use of water is vary from crop to crop, time to time, place to place.

Evapotranspiration

a) **Evaporation:** The process by which water is changed from the liquid or solid state into the gaseous state through the transfer of heat energy.

b) **Transpiration:** The evaporation of water absorbed by the crop which is used directly in the building of plant tissue in a specified time. It does not include soil evaporation.

c) **Evapotranspiration, ET:** It is the sum of the amount of water transpired by plants during the growth process and that amount that is evaporated from soil and vegetation in the domain occupied by the growing crop. ET is normally expressed in mm/day.

Factors that affect Evapotranspiration

- Weather parameters
- Crop Characteristics
- Management and Environmental aspects are factors affecting ET

Weather Parameters:

The principal weather conditions affecting Evapotranspiration are:

- Radiation
- Air temperature
- Humidity and
- Wind speed.

Crop characteristics that affect ET :

- Crop Type
- Variety of Crop
- Development Stage
- Crop Height
- Crop Roughness
- Ground Cover
- Crop Rooting Depth

Management and Environmental Factors :

- Factors such as soil salinity,
- Poor land fertility,
- Limited application of fertilizers,
- Absence of control of diseases and
- Pests and poor soil management
- May limit the crop development and reduce soil Evapotranspiration.

- Other factors that affect ET are ground cover, plant density and soil water content.
- The effect of soil water content on ET is conditioned primarily by the magnitude of the water deficit and the type of soil.
- Too much water will result in water logging which might damage the root and limit root water uptake by inhibiting respiration.

Determination of ET

- Evapotranspiration is not easy to measure.
- Specific devices and accurate measurements of various physical parameters or the soil water balance in lysimeters are required to determine ET.
- The methods are expensive, demanding and used for research purposes.
- They remain important for evaluating ET estimates obtained by more indirect methods.

Water Balance Method

- The Water Balance or Budget Method is a measurement of continuity of flow of water.
- This method consists of drawing up a balance sheet of all the water entering and leaving a particular catchment or drainage basin.
- The water balance equation can be written as:

$$ET = I + P - RO - DP + CR + SF + SW$$

- **Where:** I is Irrigation, P is rainfall, RO is surface runoff, DP is deep percolation, CR is capillary rise, SF and SW are change in sub-surface flow and change in soil water content respectively

Lysimeter Method

- A water tight tank of cylindrical shape having dia about 2 m and depth about 3 m is placed vertically in ground.
- The tank is filled with sample soil.
- Bottom of the tank consists of sand layer and a pan for collecting surplus water.
- The consumptive use of water is measured by the amount of water required for the satisfactory growth of plants with in tank.
- $C_u = W_a - W_d$ (Cu = consumptive use, Wa = water applied, Wd = Water drained off)

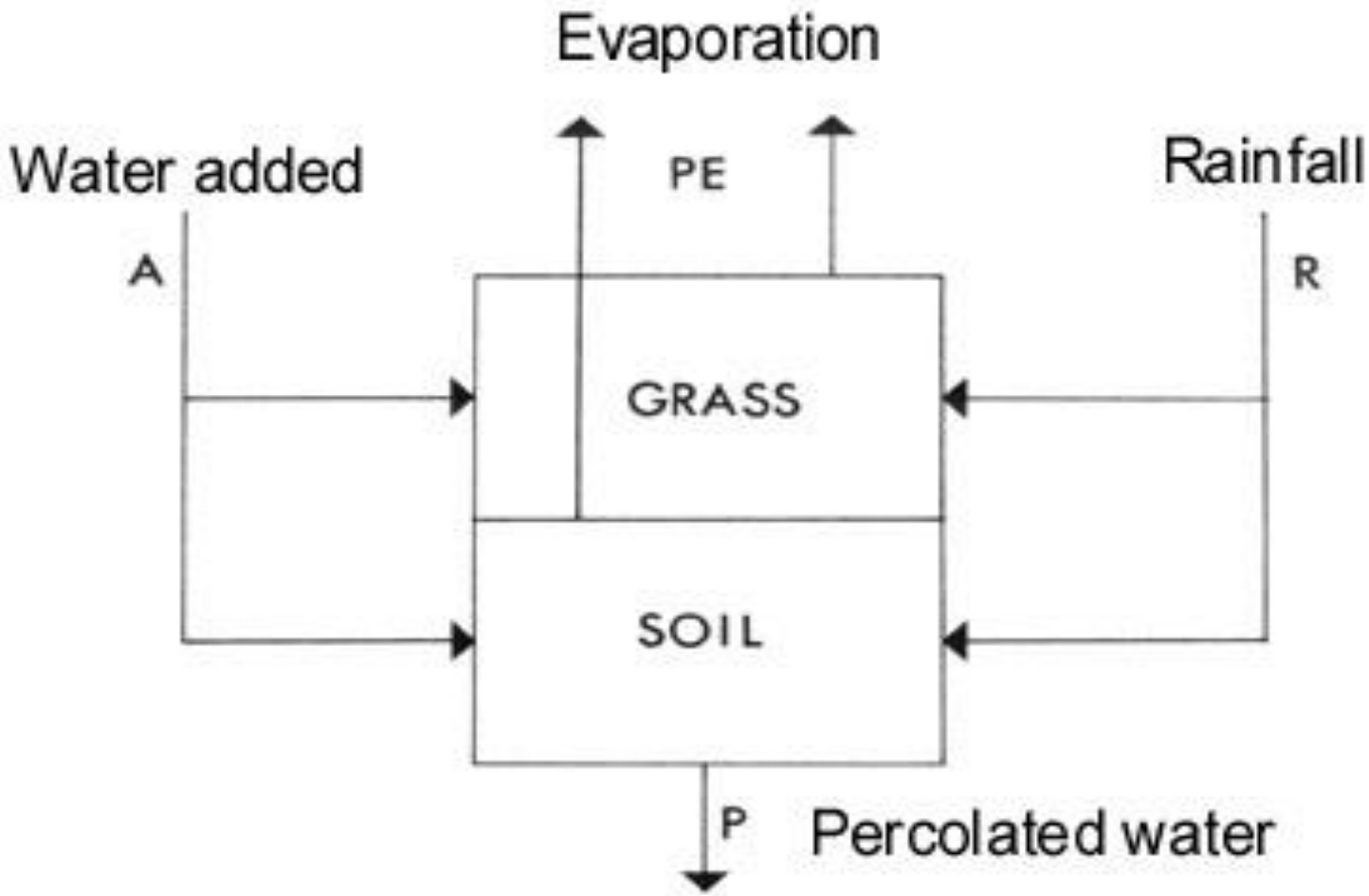


Fig 1. Simplified pathway of water in an evapotranspiration measuring apparatus

Field experimental method

- Some fields are selected for expt.
- The quantity of water is applied in such a way that it is sufficient for satisfactory growth of crops.
- There should be no percolation or deep runoff.
- If there is any runoff it should be measured and deducted from the total quantity of water applied.

Soil moisture study

- Several plots of land are selected where irrigation water is to be supplied.
- The soil samples are taken from diff depths at the root zone of the plants before and after irrigation.
- Then water contents of the soil samples are determined by laboratory tests.
- The depth of water removed from soil determined by $D_r = pwd/ 100$

  (Dr= depth of water removed in m, p = % of water content, w = sp. Gr. Of soil, d= depth of soil in m)

- The total quantity of water removed in 30 days period is calculated.
- Then a curve of water consumption versus time is prepared.
- From this curve the water consumption for any period can be calculated.

Irrigation efficiencies

- Efficiency is the ratio of the water output to the water input, and is usually expressed as percentage.
- Input minus output is nothing but losses, and hence, if losses are more, output is less and, therefore, efficiency is less.
- Hence, efficiency is inversely proportional to the losses.
- Water is lost in irrigation during various processes and, therefore, there are different kinds of irrigation efficiencies.

Efficiency of Water-conveyance (η_c)

- It is the ratio of amount of water applied to the land to the amount of water supplied from the reservoir.
- It may be represented by η_c.

$$\eta_c = (W_l/W_r) \times 100$$

- where, η_c = Water conveyance efficiency,
- Wl = amount of water applied to land, and
- Wr = Water supplied from reservoir.

Water application efficiency (η_a)

- Ratio of water stored in root zone of plants to the water applied to the land.

- Denoted by $\eta_a = (W_z/W_l) \times 100$

η_a = water application efficiency

W_z = amount of water stored in root zone

W_l = amount of water applied to land

Water use efficiency (η_u)

- Ratio of the amount of water used to the amount of water applied.
- Denoted by η_u .

$$\eta_u = (W_u/W_l) \times 100$$

η_u = water efficiency use.

W_u = water used

W_l = water applied

Consumptive use efficiency (η_{cu})

- Ratio of the consumptive use of water to the amount of water depleted from the root zone.

$$\eta_{cu} = (C_u/W_p) \times 100$$

η_{cu} = consumptive use efficiency

C_u = consumptive use of water

W_p = amount of water depleted from root zone

Standard of irrigation water

Constituent	Long-term use (mg/L)	Short-term use (mg/L)
Aluminum	5.0	20.0
Arsenic	0.10	2.0
Beryllium	0.10	0.5
Boron	0.75	2.0
Chromium	0.1	1.0
Cobalt	0.05	5.0
Copper	0.2	5.0
Fluoride	1.0	15.0
Iron	5.0	20.0
Lead	5.0	10.0
Manganese	0.2	10.0
Nickel	0.2	20.0
Zinc	0.2	10.0

Methods of Measuring Irrigation Water

a) **Direct method:** Collect water in a contained of known volume e.g. bucket. Measure the time required for water from an irrigation source e.g. siphon to fill the bucket.

Flow rate = Volume/time m^3/hr or L/s etc.

b) **Weirs:** Weirs are regular notches over which water flows.

- They are used to regulate floods through rivers, overflow dams and open channels.
- Weirs can be sharp or broad crested; made from concrete timber, or metal and can be of cross-section rectangular, trapezoidal or triangular.
- Sharp crested rectangular or triangular sections are commonly used on the farm.

- The discharge through a weir is usually expressed as:

$$Q = C\,L\,H^m$$

where Q is the discharge;

C is the coefficient dependent on the nature of weir crest and approach conditions;

L is the length of crest;

H is the head on the crest and

m is an exponent depending on weir opening.

- Weirs should be calibrated to determine these parameters before use eg. for trapezoidal weirs(Cipoletti weir),

$$Q = 0.0186\ L\ H^{1.5}$$

Q is discharge in L/s;

L, H are in cm.

c) Orifices: An orifice is an opening in the wall of a tank containing water.

- The orifice can be circular, rectangular, triangular or any other shape.
- The discharge through an orifice is given by:

$$Q = C A \quad 2 g h$$

- Where Q is the discharge rate;
- C is the coefficient of discharge (0.6 - 0.8);
- A is the area of the orifice;
- g is the acceleration due to gravity and
- h is the head of water over an orifice.

d) **Flumes:** Hydraulic flumes are artificial open channels or sections of natural channels.

- Two major types of hydraulic flumes are Parshall or Trapezoidal ones.
- Flumes need to be calibrated after construction before use.

e) **For streams, use gauging**. A current meter is used to measure velocity at 0.2 and 0.8 Depth or at only 0.6 depth.

- Measure areas of all sections using trapezoidal areas.

$$Q = ai\ vi$$

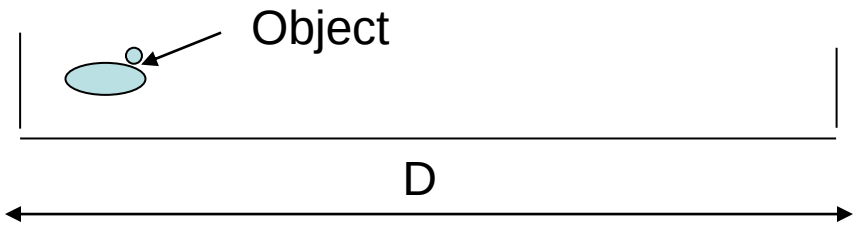
f) **Using Floats:** A floating object is put in water and observe the time it takes the float e.g. a cork to go from one marked area to another.

Assuming the float travels D meters in t secs

Velocity of water at surface = (D/t) m/s

Average velocity of flow = 0.8 (D/t)

Flow rate, Q = Cross sectional area of flow x velocity.



Thanks 2 all…